NRWA-CoRA-03-R269

Final Report

NASA Contract NASW-00040

Title: "Analysis of Diurnal, Planetary and Mean Wind Activity using TIMED, MF and Meteor Radar Winds"

PI's: Ruth S. Lieberman and Dennis R. Riggin

The goals of this project are to

1. Validate TIMED Doppler Interferometer (TIDI) winds using ground-based MF and meteor winds.

2. Examine short-term (i. e., day-to-day and week-to-week) variability of the diurnal tide.

These objectives were to have originally been met by comparing short-term diurnal tidal determinations from ground-based (GB) winds with planetary-scale diurnal definitions from TIDI winds.

We have worked closely with Dr. Qian Wu of the TIDI science team at NCAR/HAO in order to meet objective 1. We are supplying data from our radar sites at Rarotonga and Hawaii for validation of the TIDI winds, and Dr. Wu provided us with height profiles of TIDI line-of-sight winds at times when the satellite instrument track from one of the four TIDI telescopes was overflying either of our radars. Radar wind profiles have been computed, projected along the satellite look direction. So far the validation effort has focused on he 90--100 km range, where TIDI winds have the highest signal-to-noise ratio. An example scatter plot (correlation digram) of Hawaii versus TIDI winds collected between March 21 and May 20, 2002 is shown in the attached Figure 1. We are currently working on new comparisons of vector wind from radars and TIDI that will be shown at the January 2004 TIMED Review Meeting at APL. The radars used for these new comparisons are the MF and meteor radars at Rarotonga, the MF radar on Kauai, Hawaii and the meteor radar on Mauai, Hawaii. The Mauai radar is operated by University of Illinois (Steven Franke, PI) and the other radars are operated by CoRA/NWRA (Dennis Riggin, PI). Dr. Wu expects the variance of the TIDI winds to decrease, and their correlation with radar winds to increase when the TIDI line-of-sight winds are combined into vector winds.

In the absence of new satellite data, we have attempted to meet the goals in objective 2 using existing databases. We have broadened our science goals to include variability of planetary waves along with tides, as seen from satellite and ground based data. A paper has been published this year examining the evolution of the 6.5 day wave in the stratosphere, mesosphere and lower thermosphere (MLT). Our data sources included stratospheric analyses from the United Kingdom Meteorological Office (METO), HRDI MLT winds, and MR winds from Saskatoon, Urbana, Kauai, Christmas Island, Jakarta and Adelaide.

The meridional structure of the 6.5-day wave is consistent with the 5-day wave structure predicted by normal mode theory. However, during the equinox periods of 1994, when composite monthly mean HRDI winds indicate regions of instability (negative meridional gradients of zonally averaged potential vorticity), the wave amplitude increases sharply above 80 km, and phase lines acquire greater "tilt" with altitude. These features are illustrated in Figure 2. One manifestation of vertical phase tilt is that zonal and meridional winds, and meridional winds and temperatures are no longer in phase quadrature, as predicted by neutral wave theory. Instead, these pairs of variables exhibit in-phase and antiphase relationships, which lead to meridional and vertical transports of heat and momentum. Figure 3 illustrates the poleward transport of heat by the 6.5-day wave meridional winds at 90 km in HRDI retrieval. We concluded that for the equinox cases studied in 1994, the 6.5 day wave is a normal mode (a "5-day wave) modified by instability of the background state. This study is due to appear shortly in JGR-Atmospheres.

We have conducted a similar study of the 2-day wave in the boreal (Northern hemisphere) summer of 1994, using METO analyses, UARS temperatures and winds, and ground-based winds. This study is described in a paper submitted to JGR-Atmospheres. Like the 6.5-day wave, the 2-day wave is a normal mode that is subject to amplification in unstable background states. Most of the evidence in our 1994 data pointed to a high latitude source for the boreal summer 2-day wave. Figure 4 shows S-transform decompositions of meridional winds from a chain of radar sites extending from high latitudes to the equator. This result suggests that the two-day wave was pulse-like disturbance that originated at high northern latitudes and that propagated toward the equator during the summer. Little evidence was seen for a connection between the 2-day wave in the MLT, and the lower altitudes. Although the zonal components most commonly associated with the 2-day wave are wavenumbers 3 and 4, the event we studies was predominantly zonal wavenumber 2, The disturbance was highly localized in time, and propagated from the high northern latitudes toward the equator. At the stratopause and lower mesosphere heights, the largest 2-day wave amplitudes were seen in the southern (winter) hemisphere. However, the winter hemisphere wave was vertically trapped, and did not penetrate to upper mesospheric heights.

Short-term variability of the diurnal tide has been investigated in a recently upgraded version of Limb Infrared Monitor of the Stratosphere (LIMS) temperatures. LIMS sampled the 20--80 km region between October 1978-May 1979. This work is soon to be published in JASTP. Diurnal tides are inferred from differences in the dayside and nightside measurements (separated by about 9.6 hours at the equator). Our study was motivated by suggestions that nonlinear interactions between tides and planetary waves (PW's) induce short-term (i. e., day-to-day and week-to-week) modulations of tides.

Interactions between tides and stationary PW's are a source of nonmigrating tides, whose wavenumbers are given by the sum and difference of the tide and PW zonal wavenumbers. The attached Figures 4 and 5 illustrate amplifications of a stationary PW one at middle (Figure 4) and subtropical (Figure 5) latitudes during December 1978 and January 1979. Concurrent amplification of westward migrating diurnal wavenumber 2 (W2) is observed. This diurnal mode has been shown in theory to be the product of a nonlinear interaction between the migrating diurnal tide and a stationary PW 1. The correlation between PW 1 and W2 amplitudes are highest when PW 1 penetrates to subtropical latitudes.

The observed association between PW 1 and W2 supports arguments for PW-tide interactions, however, the LIMS twice-daily local time sampling confined our diurnal analyses to nonmigrating components only, at tropical latitudes. A more complete investigation of this problem requires tidal definitions at middle and high latitudes where PW's maximize.

Papers:

Riggin, D. M., R. S. Lieberman, R. A. Vincent, A. H. Manson, C. Meek, Y. Portnyagin, T. Nakamura, T. Tsuda, 2003: "The two-day wave during the boreal summer of 1994", submitted to JGR-Atmospheres.

Lieberman, R. S., D. M. Riggin, S. J. Franke, A. H. Manson, C. Meek, T. Nakamura, T. Tsuda, R. A. Vincent and I. Reid, "The 6.5-day wave in the mesosphere and lower thermosphere: Evidence for baroclinic/barotropic instability", 2003: To appear in JGR-Atmospheres.

Lieberman, R. S., J. Oberheide, M. E. Hagan, E. E. Remsberg and L. L. Gordley, "Variability of diurnal tides and planetary waves during November 1978-May 1979", 2003: To appear in JASTP.

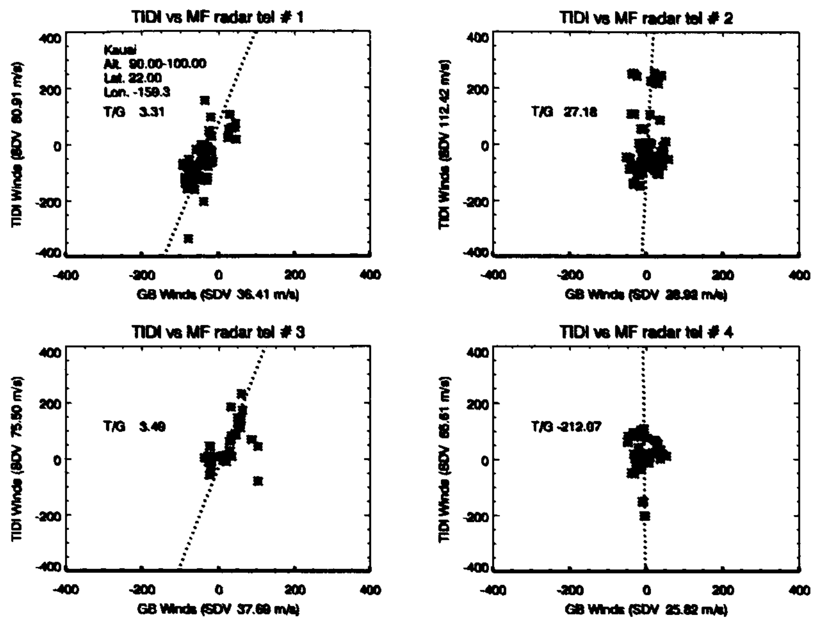

Figure 1: Scatter plot of MF winds at Kauai versus TIDI overflight winds, collected between March 21 and May 20, 2002.

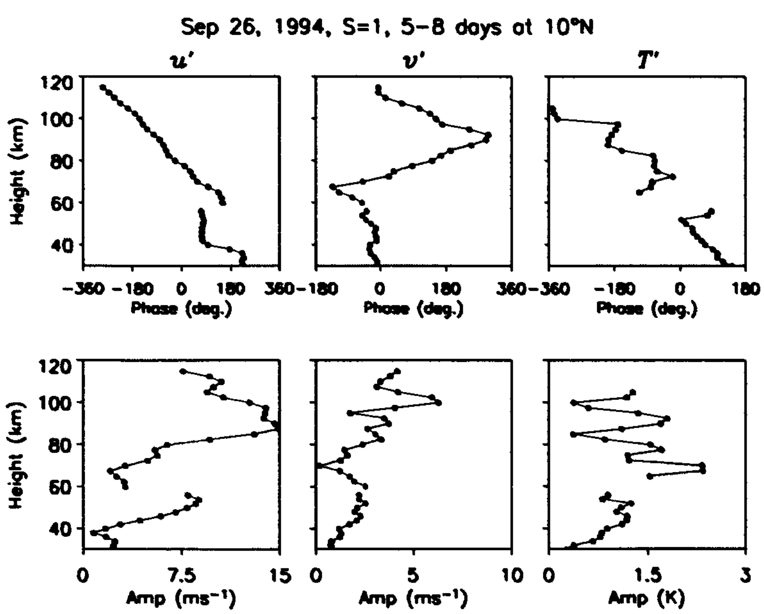

Figure 2: Phase (top) and amplitude (bottom) versus height of u' (left), v' (center) and T' on September 26, 1994.

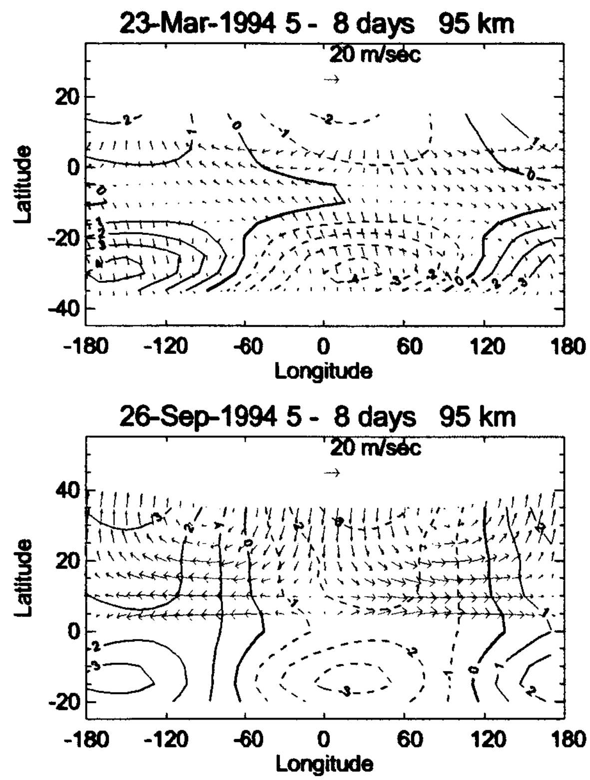

Figure 3: Latitude-longitude mappings of HRDI westward zonal wavenumber 1 T' contours and horizontal wind vectors reconstructed with periods of approximately 5.5 and 7.2 days on March 23, 1994 (top) and September 26, 1994 (bottom). Contour interval is 1 K.

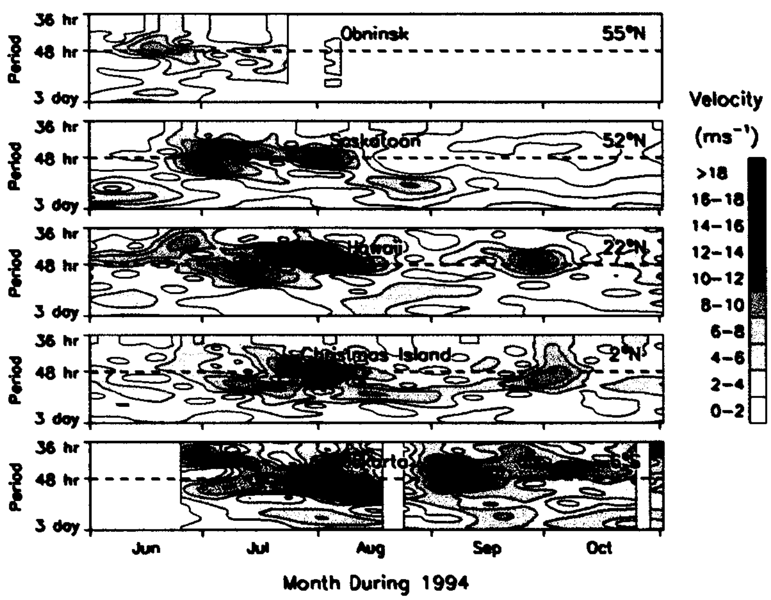

Figure 4: S-transforms of the meridional wind arranged by latitude (see label in the right-hand of each panel.

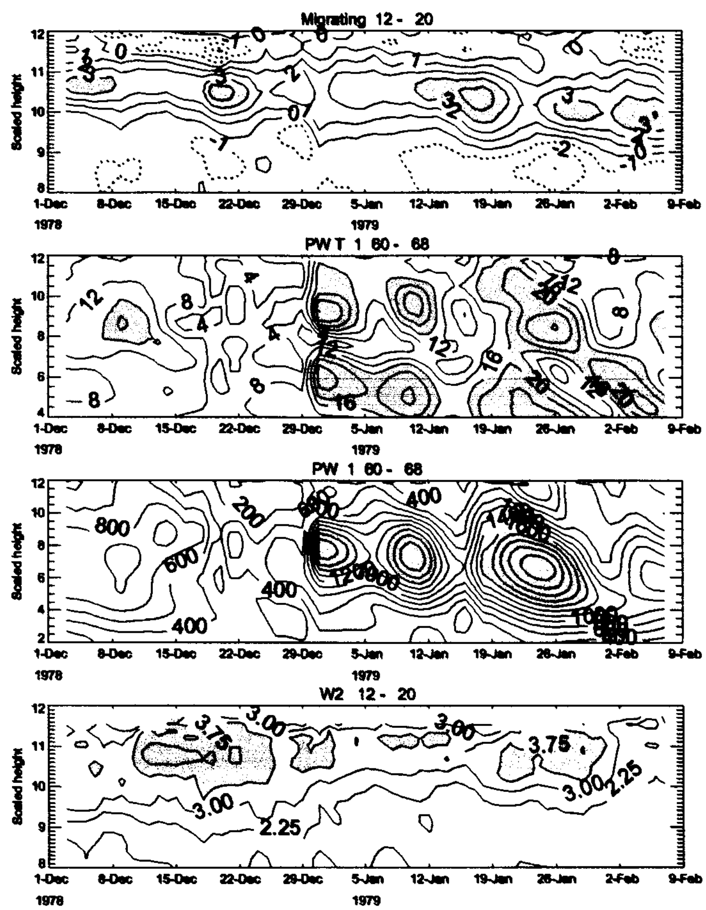

Figure 5: Top: Scaled-height versus time plots of the migrating diurnal tide temperature averaged referenced to approximately 1300 LT, averaged between 12°–20°N. Values larger than 3K are shaded. Second: PW 1 temperature amplitude averaged between 60°–68°N. Values larger than 16K are shaded. Third: PW 1 Φ amplitude averaged between 60°–68°N. Values larger than 1600 meters are shaded. Bottom: W2 temperature amplitude averaged between 12°–20°N. Values larger than 3.75K are shaded. All time series are smoothed using a 5-day running mean.

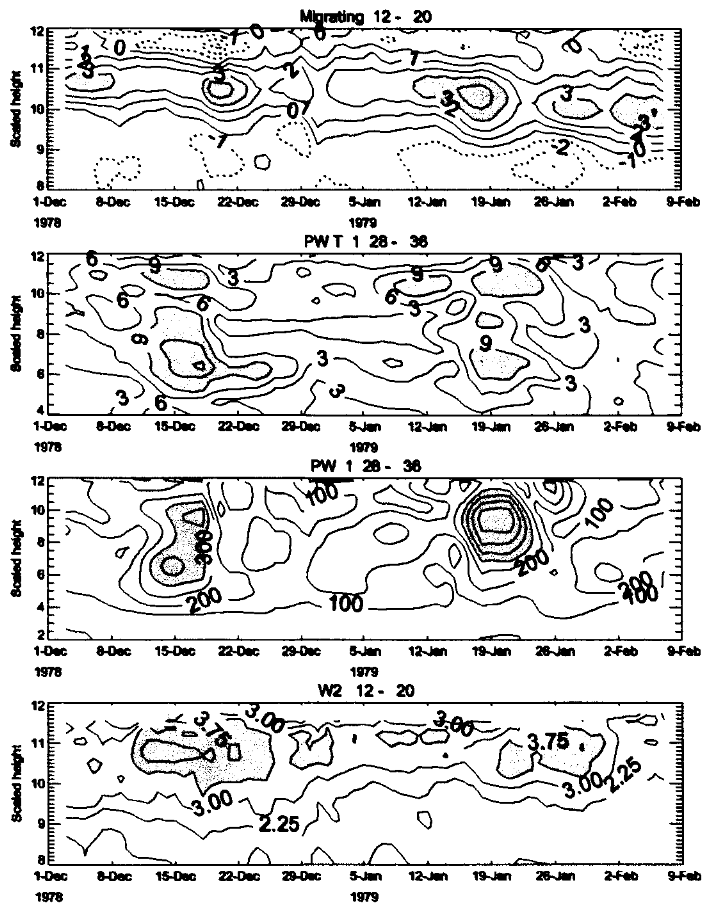

Figure 6: Top: As in Figure 5. Second: PW 1 temperature amplitude averaged between 28°–36°N. Values larger than 9K are shaded. Third: PW 1 Φ amplitude averaged between 28°–36°N. Values larger than 400 meters are shaded. Bottom: As in Figure 5. All time series are smoothed using a 5-day running mean.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	8 December 2003	Final Report 11/28/00 – 11/27/03

4. TITLE AND SUBTITLE Analysis of Diurnal Planetary Wave and Mean Wind Variability Using TIMED	5. FUNDING NUMBERS NASW-00040
6. AUTHORS Dr. Ruth Lieberman	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Northwest Research Associates, Inc. Colorado Research Associates Division 14508 NE 20th St. Bellevue, WA 98007	8. PERFORMING ORGANIZATION REPORT NUMBER NWRA-CoRA-03-R269
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Contracting Officer Code 210.H NASA, Goddard Space Flight Center Greenbelt, MD 20771	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The goals of this research are:

1. To validate TIMED Doppler Interferometer (TIDI) winds using ground-based MF and meteor winds.

2. To examine short-term (i. e., day-to-day and week-to-week) variability of the diurnal tide. This objective was to have originally been met using comparisons of short-term diurnal tidal determinations from ground-based (GB) winds with planetary-scale diurnal nonmigrating tidal definitions from TIDI winds.

14. SUBJECT TERMS	15. NUMBER OF PAGES 1
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL